Comparison of military and civilian popliteal artery trauma outcomes

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Objective: **Popliteal artery injury has historically led to high amputation rates in both the military and civilian setting. Military and civilian popliteal injury patterns differ in mechanism and severity of injury, prompting us to compare modern management and report differences in outcomes between these two patient groups. We hypothesized that whereas amputation rates may be higher in the military, this would correlate with worse overall injury severity.**

Methods: **Military casualties from 2003-2007 with a popliteal artery injury identified from the Joint Theater Trauma Registry were compared retrospectively with civilian patients presenting to a single level I institution from 2002-2009 with popliteal arterial injury. Demographics, mechanism of injury, coinjuries, Injury Severity Score (ISS), Mangled Extremity Severity Scores (MESS), interventions, and secondary amputation rates were reviewed. Descriptive statistics and unpaired *t*-tests were used to compare data. Statistical significance was $P < .05$.**

Results: **The study group of 110 patients consisted of 46 (41.8%) military and 64 (58.2%) civilians with 48 and 64 popliteal artery injuries, respectively. The military population was younger (28 vs 35 years; $P < .004$), entirely male (46 [100%] vs 51 [80%]; $P < .0001$), and had more penetrating injuries (44 [96%] vs 19 [30%]; $P < .0001$). ISS (18.7 vs 13.9; $P < .005$) and MESS (7.3 vs 5.1; $P < .0001$) were higher in the military group. Limb revascularizations in both military and civilian populations were mostly by autogenous bypass (65% vs 77%) followed by primary repair (26% vs 16%), covered stent (0% vs 6%), or other procedure (ligation and/or thrombectomy) (9% vs 1%). Fasciotomy (20 [42%] vs 37 [58%]; $P = .14$), compartment syndrome (10 [21%] vs 15 [23%]; $P = .84$), and concomitant venous repair rates (14 [29%] vs 15 [23%]; $P = .42$) were not different between cohorts. There was no difference in the fracture rate (26 [54%] vs 41 [64%]; $P = .43$), but the civilian group had a higher rate of dislocation (1 [2%] vs 19 [30%]; $P < .0001$). Secondary amputation rates were significantly higher in the military (14 [29%] vs 8 [13%]; $P < .03$).**

Conclusions: **Although both civilian and military cohorts have high amputation rates for popliteal arterial injury, the rate of amputation appears to be higher in the military and is associated with a penetrating mechanism of injury primarily from improvised explosive devices resulting in a higher MESS and ISS. (J Vasc Surg 2014;59:1628-32.)**

Traumatic disruption of the popliteal artery is a challenging injury that leads to high rates of amputation in both the military and civilian populations. Civilian amputation rates due to popliteal injury are reported as consistently lower in the literature as compared with military rates. Amputation rates in the military remain at approximately 30% for popliteal artery injury, whereas civilian amputation rates range between 14.5% to 25%.[1-5] Possible explanations for this difference include variations in factors that influence amputation outcomes including patient age, associated injuries, ischemia time, and severity of injury.[6] Civilians are typically older, sustain blunt trauma, and have varying times of ischemia before definitive repair, whereas military patients are almost exclusively young males with penetrating mechanisms of injury and relatively short transport times (<30 min).[1,2,4]

These differences, along with the limb salvage outcome discrepancy after popliteal artery injury, have prompted a comparison in contemporary management between a military and civilian cohort with the aim of understanding what factors influence differences in limb salvage rates. We aim to compare characteristics, injury patterns, and limb salvage outcomes in military and civilian patients who sustained popliteal artery trauma. We hypothesized that whereas amputation rates are higher in the military, these correlate with an increased injury severity.

METHODS

Study design and data sources. Military and civilian popliteal artery injury patients were evaluated through a retrospective study design to determine management and subsequent outcome variance. Detainees and all patients with primary amputations were excluded. Data for all

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military casualties were identified from the Joint Theater Trauma Registry. Included were military patients who sustained blunt or penetrating popliteal artery injury and presented to a level III combat support hospital located in Iraq (Baghdad or Balad) or Afghanistan (Bagram Air Field) from 2003-2007. This military group was compared with civilian patients identified from the hospital electronic medical record that presented to a single urban, level I trauma center from 2002-2009 with blunt or penetrating popliteal arterial injury.

Data collection and statistical evaluation. Arterial injury was defined as cessation of flow requiring removal of thrombus, primary repair, or revascularization with interposition grafting to restore flow to the extremity. Major amputation was limb loss at or proximal to the ankle. Any lower extremity vascular injury repaired with an expectation of permanent viability was defined as vascular limb salvage. Limb salvage failed if the limb required a major amputation as a result of vascular compromise (secondary amputation). A complication was reported if the graft failed (infection, rupture, thrombosis, stenosis, or re-intervention by thrombectomy, revision, or replacement) but the limb remained viable. Primary outcomes were graft patency (palpable pulse and normal ankle-brachial index >0.9 for military patients and normal completion angiogram for civilian patients). All procedures were performed by vascular surgeons. All military patients had definitive management of their popliteal artery injuries before or within level III centers.

Demographics, including age and sex, mechanism of injury, orthopedic coinjury, Injury Severity Score (ISS), Mangled Extremity Severity Scores (MESS), popliteal vascular reconstruction, and secondary amputation (defined as an amputation after attempted revascularization) were documented. Injury data collected regarding the injury and subsequent management included associated venous trauma, revascularization technique, conduit type, graft configuration, temporary shunting, and fasciotomy utilization. Follow-up was for up to 30 days; civilian patients has short-term follow-up until hospital discharge, whereas military patients were followed up until transfer out of the level III healthcare facility.

Descriptive statistics and unpaired *t*-tests were used to compare the data. Statistical significance was $P < .05$. This study was approved by both the military and civilian institutional review boards at The Brooke Army Medical Center, San Antonio, Texas, and the University of Texas–Houston.

RESULTS

The study group of 110 patients consisted of 46 (41.8%) military and 64 (58.2%) civilians with 48 and 64 popliteal artery injuries, respectively. The military population was younger (28 vs 35 years; $P < .004$), entirely male (46 [100%] vs 51 [80%]; $P < .0001$), and had more penetrating injuries (44 [96%] vs 19 [30%]; $P < .0001$). ISS (18.7 vs 13.9; $P < .005$) and MESS (7.3 vs 5.1; $P < .0001$) were higher in the military group. In the penetrating military subgroup, 60% were direct blast injuries and 40% were gunshot wounds with the blast wounds portending a poorer outcome within the penetrating group.

Table. Comparison of demographics, associated injuries, and outcomes between military and civilian popliteal artery injury patients

	Military, No. (%)	*Civilian, No. (%)*	P *value*
Average age	28	35	<.004
Male	46 (100)	51 (80)	<.0001
Penetrating trauma	44 (96)	19 (30)	<.0001
ISS	18.7	13.9	<.005
MESS	7.3	5.1	<.0001
Fasciotomy	20 (42)	37 (58)	.14
Compartment syndrome	10 (21)	15 (23)	.84
Concomitant venous repair	14 (29)	15 (23)	.42
Fracture	26 (54)	41 (64)	.43
Dislocation	1 (2)	19 (30)	<.0001
Secondary amputation	14 (29)	8 (13)	<.03

ISS, Injury Severity Score; *MSS,* Mangled Extremity Severity Scores.

Limb revascularizations in both military and civilian populations were mainly by autogenous bypass (ipsilateral or contralateral) (31 [65%] vs 49 [77%]) followed by primary repair (12 [26%] vs 10 [16%]), endovascular stent placement (0 [0%] vs 4 [6%]), and other (ligations and/or thrombectomy) (4 [9%] vs 1 [1%]). There was no difference in success of revascularization, based on type of repair.

Compartment syndrome (10 [21%] vs 15 [23%]; $P = .84$), concomitant venous repair rates (14 [29%] vs 15 [23%]; $P = .42$), and fasciotomy rates (20 [42%] vs 37 [58%]; $P = .14$), were not different. There was no difference in the fracture rate (26 [54%] vs 41 [64%]; $P = .43$), but the civilian group had a higher rate of posterior knee dislocation (1 [2%] vs 19 [30%]; $P < .0001$). Secondary amputation rates were significantly higher in the military (14 [29%] vs 8 [13%]; $P < .03$). All amputations were either above the knee or below the knee. The Table provides a summary of our findings.

DISCUSSION

Lower extremity arterial injury occurs in 0.39% of civilian trauma admissions, of which 22% are popliteal artery injuries.[3,4,7] The incidence of lower extremity arterial injuries is 0.28% in the military, of which 20% are popliteal.[8-11] This study was performed to compare the modern differences in popliteal artery trauma outcomes between the military and civilian patients. It is important that military data be shared in the civilian literature to help shape appropriate civilian management practices. Our data found that military patients had an increased rate of secondary amputation with injury to the popliteal artery, probably as the result of the associated soft-tissue injuries that accompany improvised explosive device (IED) injury patterns.

In the military, penetrating explosive mechanisms constitute 78% of all vascular injuries from the Iraq and

Afghanistan conflicts, the highest proportion observed in any large scale military conflict.[12-14] In our study, the majority of the injuries grouped as penetrating were from these blast mechanisms (60%) and portended poorer outcomes, probably as the result of associated soft-tissue loss and fractures. There were significantly more penetrating injuries in the military (96%) subset than the civilian group (30%), in concurrence with the literature.[4] The popliteal artery was chosen for comparative examination in this study because recent national data analysis reported that the popliteal artery was injured in half of all amputations, with isolated injury to the popliteal or tibial arteries seen frequently.[4] In the National Trauma Data Bank study, amputation was twice as frequent in the popliteal or tibial group than in the common or superficial femoral cohort, making the popliteal artery an ideal focus of "worse-case injury" comparison between the military and civilian cohorts.[4] Currently, amputation rates after popliteal artery injury range between 14.5%-25% in the literature for civilians and up to 30% in the military population.[4,5,15,16] We originally hypothesized that these reported differences in the literatures were based in increasing rates of associated vein trauma, compartment syndrome, and fracture rates in the military group. However, our data found no difference in the rates of venous injury between groups. Military studies have advocated repair of concomitant venous injuries when feasible for reduction in amputation rates; however, several recent studies, all performed in civilian settings, found no increased risk for amputation in patients with associated venous injuries regardless of attempted repair.[3-5,17-19]

Interestingly, the data from this study did not note a difference in lower extremity fracture rates or compartment syndrome rates between the civilian and military cohort. However, the mechanism of fracture injury was different between groups; military patients primarily sustained a fracture from blast injury, whereas motor vehicle crash was the most common mechanism of injury in the civilian cohort. Doucet et al[20] described the impact of a blast mechanism on limb salvage in a combat vs civilian setting and reported that patients in the military group were more severely injured, more physiologically unstable, and had a higher amputation rate for Gustillo (G) grade G-A IIIB and IIIC fractures than civilian group patients. They concluded that for the same grades (G-A IIIB and IIIC), limb salvage rates were significantly worse for open tibia fractures as a result of blast injury when compared with typical civilian mechanisms.[20] The incidence of popliteal artery injuries with fractures around the knee in the civilian literature ranges between 3-21%.[4,21] For penetrating injury, the rate of associated fracture is 42% and for blunt trauma the associated fracture rate is 88%.[22] Although fracture rates may not be different overall in our study, the types of fracture patterns may have contributed to the difference in amputation rates. Interestingly, the rates of dislocation were higher in the civilian group associated with the higher rates of blunt motor vehicle crash trauma, which results in posterior dislocation of the knee and popliteal artery injury.

Compartment syndrome has been associated with high rates of limb loss.[4] In our series, the rates of fasciotomy and compartment syndrome were not different between the military and civilian groups, which was surprising but likely reflects the period of data collection from the military (2003-2007). Current (2013) military clinical practice guidelines emphasize the necessity for casualties with lower extremity vascular injury to have fasciotomies before transport to a higher level of care. A military study that reviewed patients from 2003-2006 reported that of 4332 limb casualties, 15% underwent fasciotomy with monthly fasciotomy rates increasing from 5% to 30% over the study period. The authors concluded that between 2003 and 2006, fasciotomy rates increased because of an increasing injury severity, tourniquet utilization, and awareness of the need to perform prophylactic fasciotomy.[22] An educational program was implemented by the military in 2009 and a recent report comparing pre-education and post-education combat casualty care found an association with improved survival, higher fasciotomy rates, and fewer fasciotomy revisions.[23]

For the civilian subgroup, reported fasciotomy rates fell within the 36%-62%.[10,24,25]

In our study, ISS, MESS, and amputation rates were significantly higher in the military group.

Although not a faultless scoring system, MESS has been shown in multiple studies (civilian and military) to serve as the best predictor of successful revascularization.[26-28] Our data suggest that management of ballistic extremity injuries in military patients should be considered separate from that of civilians with high-energy trauma extremity injuries.[29] IEDs, the most common mechanism of injury in the military cohort, result in a variety of complex, severe injuries possibly including traumatic amputation of one leg, severe injury to another extremity, severe burn, traumatic brain injury, and pelvic, abdominal, and/or urogenital wounding. Brown et al[29] reviewed the MESS in regard to the military population and concluded that the MESS did not help decide whether or not an amputation was appropriate and in particular, that age was irrelevant.[29] Surgeons should therefore be cautious when interpreting scores in the context of potential recovery from high-energy trauma.[26] However, increased ISS, as seen in the military group, is associated with worse limb salvage outcomes.[16]

Overall, our study found that military patients were younger with higher rates of penetrating injury and increased ISS and MESS, probably as the result of the predominant IED mechanism. Repairs were performed in similar fashion for both military and civilian groups, and the only difference in associated injuries was an increase in dislocation for the civilian group. However, amputation rates were significantly increased in the military cohort. This is probably due to the increased ISS and rate of IED mechanism of injury in military patients. The injury

pattern profile seen in IED use is unique and does not follow conventional outward blast patterns of injury. Rather, IEDs are associated with a "multidimensional" injury pattern of blast trauma because IED victims frequently have injury involvement of three of more body regions, with a significantly higher incidence of head, facial, and extremity trauma with perineal involvement. This is caused by the physics behind IED blast, which propels energy upward through the victim's extremities and into the torso. This pattern results in relatively minor injury to those in the vicinity but catastrophic injuries to those in direct contact with the IED.[30] This type of severe trauma has been termed "dismounted complex blast injury," which has been associated with relatively favorable survival rates but increased numbers of amputations.[31] The mortality rates for this type of injury remain paradoxically low, which is probably attributed to an organized Joint Trauma System, which includes pre-hospital tactical combat casualty care, rapid medical evacuation to a surgically capable location, and implementation of evidence-based clinical practice guidelines.

Study limitations. Wartime reporting is challenged by tactical conditions and depends on an accurate registry. Civilian data depend on the electronic medical record to capture all the vascular repairs. For the military cohort, amputation data were sometimes extracted from vascular or orthopedic clinical notes and may not have always addressed questions regarding the status of the arterial reconstruction at the time of amputation. For the civilian cohort, we were unable to determine the exact number of days from revascularization to secondary amputation; for this cohort, we were only able to ascertain that the procedure took place within 30 days of hospital admission. Furthermore, for the civilian group, we did not have access to data on physiology, transfusion, associated injuries beyond the lower extremities fractures, vein injuries, or mortality.

There are significant limitations of drawing conclusions from war data that are not always homogenous. Our military dataset was collected from 2003-2007, and numerous changes were implemented in that time that could not be controlled for in this study. Our fasciotomy rates, for example, are reported as fairly low for the military cohort, which probably is a reflection of the time period that the data were collected, given that strict adherence to the early, liberal fasciotomy policy was a function of the more recent years of this war. Follow-up was limited to the original hospital admission. Graft surveillance is an ongoing process, and further studies are required to establish the ultimate long-term impact on limb salvage in both populations.

CONCLUSIONS

Both civilian and military cohorts continue to have high amputation rates associated with the popliteal arterial injury, but the rate of amputation appears to be higher in the military. This higher rate is associated with a penetrating mechanism of injury primarily caused by IEDs, which result in a higher MESS and ISS for military patients.

AUTHOR CONTRIBUTIONS

Conception and design: AD, BP, JH, CW, CF, SC
Analysis and interpretation: AD, BP, SD, JH, CW, SC, CF
Data collection: AD, BP, SD, SC, CF
Writing the article: AD, BP, SD, JH, CW, SC, CF
Critical revision of the article: AD, BP, SD, JH, CW, SC, CF
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